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ABSTRACT

The purpose of this study was to (1) develop and validate criterion-referenced tests to measure science knowledge of students who finished the fifth grade, as well as those who finished the three cycles of the General Education and (2) to assess the performance on these tests of a national, random sample of fourth-, sixth-, seventh-, and tenth-grade students belonging to 127 public elementary and 43 public secondary schools in Costa Rica. Results show the internal consistency of the tests (calculated using KR-21) to be 0.78, 0.68, 0.83, and 0.80 for the fourth-, sixth-, seventh-, and tenth-grade levels respectively. Additional results (obtained from administering tests to 1,012 fourth-grade, 1,130 sixth-grade, 794 seventh-grade, and 449 tenth-grade students) show very low achievement in science. If the results are interpretable in terms of the objectives which were mastered by samples of students, the results are very disappointing, because of the efforts made in the last 12 years by several government agencies to improve science teaching in Costa Rica. In addition, the even lower achievement of students in some regions of Costa Rica pointed to the lack of well-prepared teachers and science materials that were found in another study conducted in those same regions. (JN)

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The Development, Validation and Administration of a Criterion-Referenced Science Battery for General Education Students in Costa Rica

by

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THE DEVELOPMENT, VALIDATION AND ADMINISTRATION OF A CRITERION - REFERENCED SCIENCE BATTERY FOR GENERAL EDUCATION STUDENTS IN COSTA RICA

Purpose

This study had two purposes. First, to develop and validate criterion - referenced tests to measure science knowledge of students that finished the fifth grade as well as the ones who finished the three cycles of the General Education. Second, to assess the performance on these tests of a national random sample of fourth, sixth, seventh and tenth graders belonging to 127 public elementary and 43 public secondary schools in Costa Rica.

Theoretical Basis for Study and Procedures

The tests developed in this study followed the definitions given by Glaser and Nitko (1971) and by Popham (1978) and can be classified as criterion - referenced achievement tests, according to the classification given by Nitko (1980). In the definition and specification of the domain measured by the tests and in the generation and selection of items, the procedures recomended by Crambert (1977), Thorndike and Hagen (1977), and Hambleton et al (1978), Hambleton (1980), Popham (1978) and Berk (1980) were followed.

SE 046 181

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To specify and define the content domain of the tests, groups of selected elementary and secondary Science teachers were chosen to elaborate lists of 25 behavioral objectives, according to a specified criterion. This criterion represented the minimum science knowledge that a student must have after he or she finished the third, sixth and nineth grade of General Education.

To define the objectives of the content domain of the tests, the teachers followed the Science programs and their Science teaching experience. After preparing their own list of objectives, each group of teachers discussed them and came up with one list. Besides, they ranked the objectives with numbers, giving number one to the most important and number 25 to the least important objective. This represented the first aproximation to the domain to be measured.

For further validation of the domain, the lists of objectives were submited to groups of Science teachers in three differents regions of the country. In a day-long meeting, these groups constructed their own lists of objectives and compared them with the lists of objectives prepared by the first groups, mentioned before. Then, they summarized both lists in a final list of 25 objectives and ranked them, using the procedure mentioned above.

After the three sets of four-ranked lists of objectives were obtained, defining the minimum knowledge that a student must have at the end of each of the three general educational cycles, a mean rank was computed on each objective. For each of the three test-content domains, the twenty objectives of the highest rank were chosen.

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Elementary and secondary science teachers were contracted and instructed to write multiple-choice items for each objective. The goal was to have at least 10 items per each objective. A panel of five Science educators judged the matching of the items with each objective. Then, these experts chose the three items that suited each objective best.

According to this procedure, each test would have sixty items, due to the fact that each test must measure the content domains defined by twenty objectives. Judges decided that the test to be administered to the fourth graders was very long for their level. Therefore, the judges eliminated 4 objectives (12 items).

The procedures followed in the definition of the domain to be measured by these tests, give evidence of the domain selection validity (Popham, 1978). The way the items were written and the judgemental procedure used to choose the items represented good evidence of the content validity of the tests (descriptive validity, Popham, 1978).

Among the several methods to estimate the reliability of the C-R tests and due to the lack of computer programs to estimate them, KR-21 was chosen, using the recomendations given by Downing and Mehrens (1978).

Since there is a high degree of attrition between sixth and seventh grades (the change from elementary to high school) in the rural areas, the researchers considered appropriate to compare the achievement of sixth-graders in rural areas to those in urban areas. In order to compare these populations, the researchers decided to modify the seventh-grade test by eliminating eighteen items from it. These items belonged to six objectives that presented the

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content of the sixth-grade science program. Kuder-Richardson-21 was performed for this test also.

Data Source

Out of a total of 206 public, secondary-high schools, a random and stratified-by region- sample of 43 institutions was chosen. The tests were administered to intact groups of ten-tenth and tenth graders in these high schools.

Out of 121 elementary schools belonging to the same school districts of the 43 high schools chose, a random and stratified sample (by size of school) of 27 elementary schools were chosen. The tests were administered to intact groups of fourth and sixth graders of these elementary schools.

One thousand and twelve fourth graders, 1,130 sixth graders, 754 seventh graders and 410 tenth graders answered the tests during the first two months of 1983 academic year.

Reliability

The internal consistency of the tests calculated using KR-21 (Kuder and Richardson, 1937) were: 0.70; 0.68; 0.83 and 0.80 for the fourth, sixth, seventh, and tenth grade levels, respectively.

According to Rhodes and Davis (1979), mastery standards for each objective in each test were established. This procedure [illegible] the standard deviation of chance scores and the criterion stated by Cullinan (1968) to set the cut off score [illegible]

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one or two standard deviation of a chance score should not be interpreted as significant of any knowledge of subject matter of the examination". These scores were arbitrarily set at two-standard deviation above the chance score. For the fourth, sixth and seventh grade tests it was 2,63 and for the tenth grade level test was 2,25.

The results pointed out that only the fourth-graders sample in one of the seven educational regions of the country showed mastery of two out of 50 objectives measured by the test. These two objectives were: "To identify the function of the organs of the senses", and "To recognize the water, the soil and the air as factors of life". The complete lists of objectives and their means can be seen in tables 1, 2, 3 and 4. No other objective was mastered in any other grade level, even though the analysis was conducted by region, by size of elementary school, by type of high school or including the whole national sample.

Insert Tables 1, 2, 3 about here

The normative data of tests is presented in tables 5, 6 and 7. In table 5 the means and standard deviations for the national sample and sampled regions are presented. In general, the achievement is very low. When analysis of variance was performed with these data, there were significant differences between regions to an alpha level of 0,0001 in all of the four grade levels. Test of the means a-posteriori showed significant differences at an alpha level of 0,05 as follows:

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a) in fourth grade between the Northern region and the Atlantic, Chorotega and Eastern regions; b) in sixth grade the Central region is different from the North, Chorotega and the Brunca regions; c) in seventh grade, the Eastern region is different from the Chorotega region and in tenth grade there are only significant differences between the Eastern region and the Central and Atlantic regions.

Insert tables 6, 6, 7 about here

In tables 6 and 7 the means and standard deviations by type of elementary and secondary schools are presented. It can be noticed that the achievement is lower for the smaller schools (PEQUE) and higher for the bigger schools (GRAN 4 and 5) for both grade levels (fourth and sixth). The analysis of variance on this data resulted in significant differences between types of elementary schools at an alpha level of 0,0001%. In table 7 it can be observed that for the seventh grade level the achievement of the Academic high schools is higher than the Evening Academic and Technical high schools, but in the tenth grade level this trend did not repeat, the Evening Academic high schools showed better achievement than the other two types of high schools. The analysis of variance on this data resulted in significant differences too (α = 0,005).

Conclusions

This study represents the first attempt to develop and validate criterion - referenced tests to measure Science knowledge in Costa Rica. From this perspective the tests can be useful to

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researchers, evaluators and curriculum developers at the state universities and at the Ministry of Education.

The results obtained from the administration of this test to the samples used in this study showed very low achievement in Science. If the results are interpretable in terms of the objectives which were mastered by samples of students the results are very desappointed, because of the efforts made in the last 10 years by several goverment agencies to improve Science teaching in the country. From the normative point of view the results confirmed the low achievement, since the means of the tests did not reach 60% of the total of the points of them, moreover the even lower achievement of showed by the students of rural regions of Costa Rica pointed to the lack of well prepared teachers and Science materials that were found in the study by Quesada et al (1985) in those same regions.

Finally, the results of the study should be a warning to the Science educator at the Ministry of Education and at the state universities in order to duplicate the efforts toward better in -service teacher preparation and an in -depth revision of the Science Curricula.

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Table 1

Objetives and scope of the C-S test administered to the fourth graders - sample by type of elementary school and by region

OBJETIVES		SIZE OF SCHOOL				REGION						
	National	P_{1-2}	P_{3}	P_{3-5}	P_{6-8}	Central	Eastern	Western	Territorys	Bronce	Atlantic	Northern
1- To classify the things around us by some of their physical characteristics.	1.870	1.82	1.81	1.76	2.00	1.97	1.69	2.00	1.83	1.70	1.61	2.33
2- To use the cardinal points to locate things in the space.	1.667	1.11	1.33	1.54	1.56	1.75	1.38	1.65	1.33	1.51	1.16	1.73
3- To identify some elements of the solar system.	1.880	1.54	1.57	1.89	2.04	2.07	1.90	1.85	1.69	1.70	1.14	2.38
4- To identify the functions of the organs of the senses.	2.406	2.24	2.36	2.36	2.51	2.50	2.31	2.56	2.33	2.51	2.07	*2.65
5- To recognize the water, the soil and the air as factors of life.	2.320	2.09	2.25	2.27	2.46	2.37	2.36	2.42	2.27	2.20	2.06	*2.67
6- To determine the importance of the soil as a natural resource.	0.977	1.20	1.00	0.80	0.90	0.99	0.86	0.76	0.80	1.02	0.80	1.06
7- To explain the basic function of the skeleton, the muscles and the joints.	1.025	0.97	1.00	0.93	1.11	1.06	0.90	1.07	1.06	1.10	0.85	1.13
8- To recognize the common characteristics between animals and plants.	1.581	1.37	1.49	1.56	1.60	1.67	1.35	1.60	1.57	1.61	1.42	1.75
9- To determine the utility of some animals and plants to man.	2.353	2.20	2.38	2.30	2.43	2.33	2.47	2.39	2.37	2.31	2.25	2.53
10- To recognize the form and constitution of earth.	1.252	1.10	1.27	1.19	1.33	1.25	1.16	1.30	1.21	1.30	1.18	1.40
11- To recognize the length and cause of the movements of earth: rotation and traslation.	1.905	1.39	1.71	1.87	2.10	2.11	1.79	1.93	1.68	1.93	1.55	2.33
12- To identify the phases of the hydrologic cicle.	1.698	1.62	1.56	1.72	1.70	1.85	1.62	1.65	1.68	1.75	1.52	2.00
13- To clasify the things according to their physical state.	1.640	1.37	1.35	1.60	1.82	1.75	1.52	1.80	1.50	1.66	1.35	1.79
14- To recognize that the air and other things are matter and occupy a place in the space.	1.060	0.83	0.85	1.06	1.17	1.19	0.93	1.06	1.03	1.08	0.81	1.31
15- To determine the importance of the practice of hygienic habits.	2.305	2.06	2.27	2.37	2.50	2.51	2.31	2.52	2.40	2.41	2.00	2.63
16- To apply security norms on the prevention of accidents.	1.760	1.45	1.53	1.81	1.84	1.82	1.85	1.98	1.67	1.66	1.51	1.69

* Values higher than the cut-off score, (2.43)

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Table 3

Objetives and means of the C - R test administered to the sixth grade sample by type of school and by region

OBJETIVES		SIZE OF SCHOOL				REGION						
	National	$PEGR_{1-2}$	$DEGR_{1}$	$DEGR_{2-3}$	$DEGR_{4-5}$	Central	Eastern	Western	Chorotega	Brunca	Atlantic	Northern
1- To identify some factors that contaminate air and water.	2.076	1.66	1.83	2.01	2.26	2.18	2.31	2.06	1.85	2.09	1.92	1.78
2- To differentiate the concepts tissue, organs and systems.	1.498	1.05	1.14	1.58	1.61	1.64	1.66	1.56	1.24	1.32	1.36	1.27
3- To classify the animals according to their common characteristics (vertebrate and invertebrate).	1.185	1.29	1.07	1.13	1.28	1.28	1.13	1.30	1.22	0.99	0.96	1.30
4- To classify substances according to their physical propieties.	1.674	1.15	1.38	1.72	1.80	1.84	1.72	1.70	1.45	1.50	1.60	1.47
5- To classify food according to its organic composition.	1.844	1.68	1.71	1.99	1.87	1.77	1.94	1.85	1.87	1.85	1.97	1.77
6- To recognize how the water, the air and the soil - types influence plants and animals.	2.023	1.73	1.96	1.97	2.11	2.07	2.15	2.01	1.92	1.98	1.93	1.95
7- To recognize the consequences of the rotation and translation movements of earth.	0.832	0.73	0.76	0.86	0.84	0.96	0.79	0.91	0.61	0.72	0.73	0.73
8- To recognize the components of the solar system.	1.240	0.95	1.07	1.21	1.35	1.42	1.06	1.26	1.10	1.25	1.05	1.41
9- To differentiate the function of each part of a plant.	1.003	0.97	0.78	1.05	1.05	1.06	1.18	1.04	0.85	0.98	0.89	0.80
10- To differentiate the main characteristics between vertebrates and invertebrates.	1.844	1.22	1.46	1.89	2.01	1.97	2.09	1.84	1.56	1.76	1.64	1.69
11- To identify the main bones and muscles of the human body.	1.432	1.37	1.32	1.51	1.42	1.48	1.48	1.41	1.45	1.41	1.37	1.31
12- To identify the main functions that are accomplished by the living beings.	1.895	1.49	1.67	1.93	1.99	1.96	2.01	1.87	1.87	1.89	1.78	1.73
13- To recognize the physical and chemical transformations of food in the digestive process.	1.451	1.10	1.37	1.52	1.45	1.55	1.50	1.33	1.38	1.52	1.32	1.40

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Table 3

Objetives and means of the C - R test administered to the seventh grade sample by type of high school and by region

OBJETIVES		TIPE OF HIGH SCHOOL			REGION						
	National	Day Academic	Night Academic	Technical	Central	Estern	Western	Chorotega	Brunca	Atlantic	Northern
1- To Identify some factors that contaminate air and water.	2.259	2.35	2.30	2.02	2.31	2.23	2.07	1.98	2.25	2.26	2.40
2- To differentiate the concepts: tissue, organs and systems.	1.589	1.67	1.53	1.42	1.62	1.65	1.60	1.34	1.54	1.71	1.37
3- To classify the animals according to their common characteristics (vertebrate and invertebrate).	1.042	1.02	1.10	1.07	1.04	1.03	1.07	1.00	1.05	0.97	1.23
4- To establish the survival relationships among living beings which are part of a food chain	1.495	1.58	1.23	1.43	1.47	1.80	1.16	1.38	1.75	1.26	1.70
5- To classify substances according to their physical ropieties.	1.931	2.05	1.99	1.61	1.93	2.21	2.00	1.55	1.92	1.74	2.00
6- To classify food according to its organic composition	1.793	1.81	1.76	1.78	1.71	2.09	1.64	1.98	1.97	1.74	1.97
7- To recognize how the water, the air and the soil - types influence plants and animals.	2.053	2.11	2.04	1.92	2.02	2.26	2.00	1.96	2.14	2.11	2.07
8- To recognize the consequences of the rotation and translation movements of earth.	0.902	0.97	0.77	0.82	0.92	1.03	0.89	0.74	0.88	0.76	0.83
9- To recognize the components of the solar system.	1.296	1.32	1.28	1.26	1.31	1.49	1.24	1.06	1.15	1.21	1.50
10- To differentiate the function of each part of a plant.	1.111	1.17	1.05	1 00	1.11	1.30	1.13	1.00	0.95	1.11	1.10
11- To differentiate the main characteristics between vertebrates and intervetrates.	1.943	2.05	1.82	1.76	1.91	2.12	1.75	1.85	2.10	1.97	2.13
12- To identify the main bones and muscles of the human body.	1.528	1.58	1.56	1.37	1.47	1.71	1.66	1.43	1.58	1.69	1.53
13- To identify the main functions that are accomplished by the living beings.	1.961	1.99	2.16	1.78	1.94	2.02	1.89	1.91	1.97	2.05	2.30
14- To recognize the plysical and chemical transformations of food in the digestive process.	1.501	1.54	1.59	1.36	1.50	1.41	1.71	1.25	1.53	1.53	1.73
15- To identify the characteristics of the reproduction in plants, animals and human beings.	1.404	1.45	1.40	1.28	1.37	1.63	1.31	1.15	1.59	1.45	1.43
16- Taking in to account the concept of ecosystem, to explain some relationships among the living beings, their biotic and abiotic environment	1.720	1.80	1.71	1.54	1.69	1.96	1.67	1.62	1.66	1.74	1.83
17- To identify the lithosphere as a part of the solid structure of earth.	1.096	1.21	1.08	0.83	1.10	1.21	1.26	0.77	0.98	1.13	1.00
18- To explain the origin of the different types of rocks.	1.319	1.38	1.28	1.18	1.29	1.58	1.09	1.15	1.44	1.32	1.57
19- To identify different sources to produce electricity	1.685	1.80	1.72	1.38	1.72	1.97	1.62	1.21	1.53	1.50	1.87
20- To recognize physical and chenical changes.	1.445	1.48	1.61	1.28	1.42	1.57	1.56	1.42	1.48	1.50	1.20

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Table 4

Objetives and means of the C - R test administered the tenth graders - sample by type of high school and by region

OBJETIVES		TYPE OF HIGH SCHOOL			REGION						
	National	Day Academic	Night Academic	Technical	Central	Eastern	Western	Chorotega	Brunca	Atlantic	Northern
1- To explain the concept of Science in terms of process and product.	1.047	1.12	0.99	0.97	1.01	1.36	0.94	1.02	1.16	1.00	1.06
2- To describe the mutual dependence between the soil and the living beings.	1.312	1.28	1.44	1.31	1.27	1.56	1.40	1.13	1.29	1.38	1.50
3- To explain the importance of the sun in the development of the different living beings.	0.844	0.86	0.79	0.85	0.89	0.94	1.02	0.69	0.66	0.75	0.75
4- To explain the composition and formation of the soil	1.343	1.28	1.61	1.32	1.29	1.33	1.57	1.52	1.24	1.30	1.25
5- To establish the interations, that take place in a determined ecosystem between the biotic and abiotic enviroments.	1.189	1.22	1.17	1.15	1.08	1.69	1.28	1.35	1.11	1.11	1.19
6- To identify the most relevant physical and chemical characteristics which define the Atmosphere, Geosphere and Hydrophere of the earth.	0.771	0.75	0.70	0.83	0.80	0.89	0.75	0.88	0.50	0.75	0.63
7- To relate the characterictics of each layer of the atmosphere with its function.	0.791	0.82	0.90	0.69	0.81	0.97	0.77	0.79	0.76	0.60	0.88
8- To differentiate tissue, organ and system or apparatus.	1.372	1.35	1.32	1.43	1.31	1.39	1.40	1.56	1.29	1.43	1.56
9- To explain some energy transformations.	0.757	0.86	0.63	0.66	0.68	1.17	0.62	0.79	0.92	0.87	0.50
10- To explain some atmospheric phenomena that are important to The harmonious development of life.	1.285	1.27	1.49	1.20	1.15	1.56	1.57	1.31	1.53	1.21	1.19
11- To distinguish between sexual and asexual reproduction.	1.367	1.32	1.49	1.39	1.32	1.53	1.45	1.50	1.52	1.23	1.06
12- To explain the atom structure.	1.045	1.08	1.14	0.94	1.03	1.11	1.06	1.29	1.00	0.85	1.31
13- To explain the different forms of energy.	0.864	0.85	0.86	0.90	0.80	0.81	0.77	1.06	1.00	0.98	0.88
14- To analize the action of the different external and internal Agents which modify the earth relief.	0.984	1.10	0.89	0.84	1.04	1.33	0.89	0.79	0.90	0.89	0.81
15- To recognize the factors that cause biological back of balance.	1.343	1.39	1.39	1.24	1.33	1.56	1.57	1.10	1.16	1.43	1.25
16- To recognize the propieties of matter.	1.272	1.25	1.54	1.18	1.19	1.58	1.36	1.38	1.24	1.30	1.06
17- To differentiate the states of matter.	1.285	1.45	1.27	1.03	1.32	1.53	1.30	1.00	1.40	1.13	1.25
18- To describe the importance of food chains	1.053	1.08	1.21	0.93	1.09	1.31	1.06	0.94	0.97	0.94	0.81
19- To name the parts and organs of an animal and a vegetal cell.	1.305	1.34	1.34	1.23	1.29	1.75	1.19	1.23	1.13	1.30	1.56
20- To recognize the importance of the photosyntesis to maintain life on earth.	0.846	0.72	0.97	0.99	0.75	0.92	1.00	1.21	0.95	0.64	0.88

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Table 5

MEANS AND STANDARD DEVIATIONS OF THE TESTS ADMINISTERES TO SAMPLES OF 4A, 6A, 7A AND 10A

GRADE LEVELS STUDENTS BY REGION 1/ 2/

GRADE	NATIONAL SAMPLE		CENTRAL		EASTERN		WESTERN		CHOROTEGA		BRUNCA		ATLANTIC		NORTHERN	
		S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
4A	2 [illegible]3	7,01	29,19	6,67	29,51	6,42	26,33	6,66	26,19	6,40	27,66	7,01	23,66	7,09	30,80	6,
6A	2 [illegible]0	5,18	21,16	5,44	21,06	5,07	20,15	5,19	18,37	4,49	19,24	5,21	18,53	4,23	19,33	4,
7A	3 [illegible]07	8,90	30,622	9,61	34,22	7,58	30,31	6,26	27,74	6,95	31,44	8,01	30,74	7,34	32,77	9,
10A	2[illegible],08	5,84	21,44	6,28	26,28	6,18	22,98	4,97	22,46	4,08	21,71	4,54	21,04	5,30	21,38	6,

1/ SAMPLE SIZE

	4A GRADE	6A GRADE	7A GRADE	10A GRADE
N. NATIONAL =	1012	1130	794	449
N. CENTRAL =	326	377	471	217
N. EASTERN =	103	128	88	36
N. WESTERN =	186	178	55	47
N. CHOROTEGA=	101	100	53	48
N. BRUNCA =	84	130	59	38
N. ATLANTICA=	161	139	38	47
N. NORTE =	51	78	30	16

2/ TOTAL POINTS OF THE TE

4A = 48
6A = 39
7A = 60
10A = 60

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Table 6

MEANS AND STANDARD DEVIATIONS OF THE TESTS ADMINISTERED TO SAMPLES OF 4A AND 6A GRADE LEVEL STUDENTS BY TYPE OF ELEMENTARY SCHOOLS

TYPE OF SCHOOL / GRADE LEVEL	NATIONAL			PEGB-2			DEGB-1			DEGB-2 y 3			DEGB-4 y 5		
	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S
4A	1012	27,53	7,01	71	24,11	6,75	146	25,81	6,39	389	27,05	6,83	406	29,90	7,02
6A	1130	20,00	5,18	41	16,39	3,96	195	17,52	4,63	403	20,28	5,17	491	21,05	5,04

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Table 7

MEANS AND STANDARD DEVIATIONS OF THE TEST ADMINISTERED TO SAMPLES OF 7A AND 10A GRADE LEVEL STUDENTS BY TYPE OF HIGH SCHOOL

GRADE LEVEL \ TYPE OF HIGH SCHOOL	NATIONAL			ACADEMIC			EVENING ACADEMIC			TECHNICAL		
	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S
7A	794	31,07	8,90	489	32,31	8,00	107	30,98	7,76	198	28,08	10,71
10A	449	22,08	5,84	236	22,37	5,56	71	23,14	5,14	143	21,06	6,47

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